U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: **INSTRUCTIONS FOR CONTINUED AIRWORTHINESS: FOCUSED INSPECTION OF SAFETY CRITICAL TURBINE ENGINE PARTS AT PIECE-PART OPPORTUNITY**

Date: **xx/xx/xx**
Initiated By: **ANE-110**

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Change:

1. **PURPOSE**. This advisory circular (AC) provides guidance and acceptable methods, but not the only methods, that may be used to demonstrate compliance with the requirements of Title 14 of the Code of Federal Regulations (14 CFR) Section 33.4, Instructions for Continued Airworthiness (ICA), relating to focused inspections of safety critical turbine engine parts. The need for focused inspections is determined by a qualitative assessment of the safety implications of a cracked safety critical part. The focused inspections should be conducted each time one of these safety critical parts is completely disassembled.

2. **RELATED REGULATIONS (CFR)**.

a. Section 33.4, Instructions for Continued Airworthiness.

b. Part 33 Appendix A, Sections A33.3(a)(6) and A33.3(b)(2), Instructions for Continued Airworthiness.

3. **RELATED REFERENCE MATERIAL**.

a. AC 33-2B, Aircraft Engine Type Certification Handbook, dated June 30, 1993.

b. AC 33.4-1, Instructions for Continued Airworthiness, dated August 27, 1999.

c. Joint FAA AIA report titled: Propulsion System and Auxiliary Power Unit (APU) Related Aircraft Safety Hazards, dated October 25, 1999.

4. **DEFINITIONS**. The following terms are defined for the purpose of this AC:

a. Automated. Any inspection technique performed by a mechanized or computerized scanning device.

b. CAAM Level 3 Hazard or Event. A propulsion system or auxiliary power unit (APU) malfunction that involves substantial damage to the aircraft or second unrelated system, small penetrations of aircraft fuel lines or aircraft fuel tanks, significant damage to a second engine system, uncontrolled fires extinguished by on-board aircraft systems, rapid cabin depressurization, permanent loss of thrust or power greater than one propulsion system, inability to climb and fly 1000 feet above terrain, or impairment of aircraft controllability.

c. CAAM Level 4 Hazard or Event. A propulsion system or APU malfunction that involves forced landing, loss of aircraft (hull loss), fatalities or serious injuries.

d. Critical Feature. A part feature identified as having a relatively high likelihood of initiating a defect. Defect initiation may be caused by high stress, low tolerance to material anomalies, susceptibility to handling damage, foreign object damage (FOD) or other causes.

e. Damage Tolerance. An element of the turbine engine component design and life management process that accounts for potential component imperfections. Component imperfections could result from inherent material structure, material processing, component design, manufacturing or usage. Damage tolerance addresses this situation through the incorporation of fracture resistant design, fracture-mechanics, process control, or nondestructive inspection.

f. Eddy Current Inspection (ECI). A nondestructive testing method in which eddy current flow is induced in the test object. Changes in the flow caused by variations in the specimen are detected by a nearby coil, coils, or Hall effect device for subsequent analysis by suitable instrumentation and techniques.

g. Fluorescent Penetrant Inspection (FPI). A surface defect detection process that uses a penetrating fluid with a fluorescent suspension to enter defect separations by capillary action. A black light is used to visually detect defects containing this fluid.

h. Focused Inspection. Detailed inspection of a specific critical feature or area of a part.

i. Hazard Ratio. The percent of total events of a particular turbine propulsion system or APU malfunction or failure that has serious or severe consequences (i.e., hazard level 3 or 4).

j. Line-of-Sight. Qualitative assessment of the ability to visually inspect piece-part features. Deep holes or features that are obstructed by adjacent part features, narrow access passages, etc., are considered to have poor "line-of-sight" inspection capability.

k. Nondestructive Inspection. Any inspection that identifies stress, strain, dimensional, defect or crack characteristics without compromising the integrity or airworthiness of the part.

l. Piece-Part Opportunity. The opportunity to perform focused inspections on safety critical parts when such parts are completely disassembled in accordance with the TC Holder's maintenance or overhaul manual instructions. Inspections are triggered by opportunity, not by a time or cyclic interval requirement. Parts that are configured with riveted, pressed-on, or otherwise attached hardware whose removal is likely to expose the part to additional damage should not necessarily be further disassembled to accommodate focused inspection. The TC holder should determine at which disassembly level the part will have minimum damage exposure and will be sufficiently disassembled to allow for inspection of the part.

m. Probability of Detection (POD). A quantitative statistical measure that detects a particular type of anomaly (flaw) over a range of sizes using a specific nondestructive inspection technique under specific conditions.

n. Safety Critical Parts. Those parts of an engine whose failure is likely to directly present a CAAM level 3 or 4 hazard to the aircraft.

o. Uncontained Failure. A significant safety event that initiates from an uncontained release of debris from an engine component malfunction (blade, disk, spacer, impeller, drum/spool, pressure vessel). In order to be categorized as uncontained for the purposes of this AC, the debris must pass completely through the nacelle. Parts or fragments that puncture the nacelle skin but do not escape or pass completely through are considered contained. Parts or fragments that pass out of the inlet or exhaust opening without passing through any structure are not considered "uncontained."

5. **<u>BACKGROUND</u>**. Analysis of ten years of transport aircraft accident and incident data shows that the leading turbine engine unsafe condition is the uncontained failure of safety critical parts. The failure of safety critical parts can present a significant hazard to an aircraft by releasing fragments that can penetrate the cabin or fuel tanks, damage control surfaces, or sever flammable fluid or hydraulic lines. To reduce the occurrence of these incidents, parts and part features most critical to safety should be subjected to focused inspections at piece-part opportunities, using methods that detect flaws that could lead to failure.

a. In day-to-day operation, many engine parts are exposed to high thermal and/or mechanical loads. As a result of these loads, defects can form. If these defects are not detected, they can grow and lead to part failure. Defects can form for many reasons, including the following:

(1) Material impurities.

(2) Machining during manufacture or repair.

(3) Unexpected stress levels due to part design and/or operation.

(4) Unanticipated operating conditions.

(5) Foreign object damage.

(6) Handling damage during overhaul.

(7) Corrosion.

b. As a part of the certification plan, the applicant should identify the safety critical parts likely to result in a CAAM level 3 or 4 event if they fail (high hazard ratio). When the inspections of these parts and features are included in the airworthiness limitations section (ALS) of the ICA required by §33.4, the inspections become mandatory operational restrictions.

c. The incorporation of damage tolerant design methods acceptable to the administrator will enable a TC Holder to evaluate the vulnerability of a safety critical part to anomaly threats. Therefore, TC Holders who have designed safety critical parts using a damage tolerant design methodology may establish in-service focused inspections based on the part's damage tolerant characteristics and analyses.

6. **CRITICAL PARTS AND FEATURES IDENTIFICATION**. Effective focused inspections include identification of the safety critical parts, the most critical features, and the inspection processes that reliably detect defects. Each applicant should conduct an assessment to establish which parts and part features are candidates for focused inspection.

a. Selection of Parts. The primary consideration for the selection of safety critical parts requiring focused inspection is the consequence of failure of the part. Parts whose failure is likely to result in a CAAM level 3 or 4 event are potentially hazardous to the aircraft and therefore should be subject to focused inspection.

(1) Methods for identifying safety critical parts and features should incorporate the following:

(a) Service experience of similar parts.

(b) Kinetic energy analyses of the part at operational levels.

(c) Design and material characteristics of the part.

(d) Characteristics of the surrounding containment structure.

(e) Expected operating environment of the part.

(f) Production process characteristics.

(2) The selected parts should include high energy parts such as: fan disks and hubs, high pressure turbine (HPT) disks, low pressure turbine (LPT) disks, high pressure compressor disks and drum rotors. Also, special consideration should be given to some parts on large engines, such as cooling plates, shafts and spacers, due to their mass. For parts with high hazard ratios, focused inspection requirements should be included in the ALS of the ICA.

(3) If there is insufficient field experience to accurately determine the likelihood and consequence of failure, design configurations should be qualitatively evaluated using the most relevant field experience and the safety assessment conducted for certification. The qualitative assessment should include, but is not limited to, the following factors:

(a) Stress level relative to material capability.

(b) Crack growth rate.

(c) Crack path and the most critical fracture pattern.

(d) Kinetic energy of fragments of similar components that had previous CAAM level 3 and 4 events.

(e) Potential defect/damage types.

b. Feature Identification. Once the list of safety critical parts has been established, a historical review of similar parts in the field should be conducted.

(1) This review should incorporate the following factors:

(a) Failure history.

(b) Failure root causes.

(c) Feature history.

(d) Susceptibility to handling and foreign object damage.

(e) Susceptibility to material impurities.

(2) CAAM and mature TC holder databases have been considered acceptable for this review. The design characteristics of the part should be considered when evaluating features.

(3) When evaluating a part for focused inspection, the following characteristics should be included:

(a) Highly stressed features.

(b) Residual stresses (compressive or tensile).

(c) Peening effects on defect detection and growth rate.

(d) Feature residual life.

(e) Material characteristics.

(f) New or novel materials.

(g) Manufacturing/repair processes.

(h) Severity of operating environment (temperature, speed, corrosion, etc.).

(i) Cleaning requirements.

(4) An applicant may conduct fracture mechanics analyses to support the identification of the most critical part features.

7. **INSPECTION METHODS**. FPI and ECI are acceptable methods, but not the only methods, for defect detection. Whether FPI, ECI or another method is used, the prescribed inspection method should have the following characteristics: a demonstrated reliability of detecting defects on the targeted part feature; a well-developed process that minimizes variation; and the incorporation of process controls that maximize detection sensitivity and reliability. Focused inspections should be conducted at

each piece-part opportunity, regardless of which method is chosen, to maximize the likelihood of defect detection.

a. FPI is the most widely used turbine engine defect inspection method. Most safety critical parts currently receive global or full field FPI inspections periodically. However, poor line-of-sight features, surfaces with high residual compressive stress, rough finish surfaces, complex feature details, or hard to clean parts are not always appropriate candidates for FPI.

b. To raise defect detection capabilities to a higher level, other focused inspection techniques, such as ECI, should be considered for those features for which FPI is not considered appropriate. While probability of defect detection (POD) is important, the choice of inspection technique should not be based solely on this. POD quantification may be highly feature or user dependent and may not necessarily be accurate. Typically, ECI is appropriate for disk bores, high length/diameter (L/D) ratio holes, dovetail slots, and other highly stressed features.

8. <u>ENGINE INSTRUCTIONS FOR CONTINUED AIRWORTHINESS (ICA)</u>.

a. The engine manual ICA should contain language to include the focused inspections. The ALS of the ICA should incorporate the following factors:

(1) Definition of “piece-part” or other appropriate disassembly level.

(2) Identification of the parts requiring focused inspection.

(3) Location of the inspection instruction details.

(4) Specification of when the inspection is required.

b. TC holder ICAs are not standardized in the description of the Airworthiness Limitations Section; titles such as “Chapter 5,” “Time Limits Section,” or “Lifing Service Bulletins” are used. Engines certificated to part 33 prior to amendment 9 are subject to the establishment of limitations in accordance with §33.5, Instruction Manual for Installing and Operating the Engine, which does not require an ALS. Engines certificated to part 33 amendment 9 and later are subject to the requirements of §33.4, Instructions for Continued Airworthiness, which does require an ALS.

c. The step-by-step instructions for the actual inspections should be placed in the appropriate engine overhaul manual section or other readily accessible shop document.

d. The following, or similar language, should be incorporated in the ALS of the engine manual to assure that the focused inspections are incorporated into the operator’s continuous airworthiness maintenance plans.

“AIRWORTHINESS LIMITATIONS

MANDATORY INSPECTIONS

1. Perform inspections of the following parts at each piece-part opportunity in accordance with the instructions provided in the applicable manual chapter(s):

Part Nomenclature	Part Number (P/N)	Inspect per Applicable Manual Chapter
Fan Disk	All	72-31-xx-xxx, Fluorescent Penetrant Inspection and 72-31-xx-xxx, Eddy Current Inspection
HPT Rotor Interstage Seal	All	72-53-xx-xxx, Fluorescent Penetrant Inspection

2. For the purposes of these mandatory inspections, piece-part opportunity means:

a. The part is considered completely disassembled in accordance with the disassembly instructions in the engine manufacturer's maintenance manual; and

b. The part has accumulated more than 100 cycles in service since the last focused inspection, provided that the part was not damaged or related to the cause for its removal from the engine."

e. Applicants should submit the focused inspection ICA to the Aircraft Certification Office (ACO) responsible for overseeing that type certification project for acceptance. The ACO and an Aircraft Evaluation Group (AEG) will jointly determine the acceptability of the ICA. The AEG will review the focused inspection ICA and make recommendations on the maintenance and operational aspects. The

ACO will determine final acceptance of the completed ICA. The focused inspection instructions may be incomplete at type certification if a program exists to ensure its completion either:

(1) Prior to delivery of the first aircraft with the engine installed; or

(2) Upon issuance of a standard certificate of airworthiness for the aircraft with the engine installed, whichever occurs later.

f. Supplemental Type Certificates (STC) that incorporate safety critical parts should contain focused inspection ICA as part of the design approval. The STC applicant is responsible for producing, distributing and maintaining the required focused inspection ICA.

9. **RECORD KEEPING**. Any person who performs the focused inspection on a component or part should make an entry in the maintenance record of that component or part after inspection. Operators may incorporate the records of these inspections into existing maintenance record keeping systems.

SIGNATURE